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AN ADAPTATION OF THE MINIMUF HF PROPAGATION PREDICTION PROGRAM TO THE TI-59 CALCULATOR

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An algorithm for predicting the Maximum Usable Frequency between two points on the surface of the earth for High Frequency communications is implemented on a TI-59 hand-held programmable calculator.

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ABSTRACT

An algorithm for predicting the Maximum Usable Frequency between two points on the surface of the earth for High Frequency communications is implemented on a TI-59 hand-held programmable calculator.

1. INTRODUCTION

An algorithm for predicting the Maximum Usable Frequency (MUF) in the High Frequency radio band has been developed at the Naval Ocean Systems Center, San Diego, California, by R.B. Rose and J.N. Martin [1], and has been implemented in both FORTRAN IV and BASIC computer languages under the name MINIMUF-3.5. The algorithm has been incorporated into the CLASSIC PROPHET propagation analysis system, and has been demonstrated to provide a field-deployable capability for computing HF propagation paths with micro-computer resources.

2. OBJECTIVE

The essential portions of MINIMUF-3.5 are contained in approximately 80 BASIC language statements, reproduced in appendix A, which suggests a potential for being encoded in hand-held programmable calculators. H.F. Hite of Hughes Aircraft Company adapted a restricted version of MINIMUF-3.0 for the HP-67 calculator that computes MUFs for 1-hop F-layer propagation and is thus limited to station separations of 4000 kilometers or less. A complete implementation of MINIMUF, capable of 2-hop path prediction, was desired.

3. PROGRAM DEVELOPMENT

A TI-59 calculator program was adapted directly from the Rose and Martin BASIC program listing with some logic changes required to accomodate the memory constraints of the calculator. The program listing, summary of logic changes, operating instructions, and test case are contained in appendices B, C, D, and E, respectively. The program listing is annotated with cross-references to statements in the BASIC listing for assistance in tracing logic flow. The bulk of the development task was to minimize program and data storage requirements. Several iterations finally produced the current version which requires 800 program steps and 20 data registers, the full capacity of the normally-accessible calculator attributes.

4. PERFORMANCE

The TI-59 program was optimized for storage, that being the overriding constraint. Execution time for single-hop predictions is approximately 50 seconds. Were the program optimized for speed, given a larger storage capacity, execution time could conceivably approach 40 seconds. The test case contained in appendix E is the identical test case promulgated with the Rose and Martin report, and yields the same results on the TI-59. Notice, however, that the MUF limit of 32 MHz has been raised to 50 MHz, thereby providing

for HF path prediction during periods of high solar flux when customary band limitations are exceeded. The test case should be executed after initially programming the TI-59 by keystroke to ensure correct program entry. A copy of the program is available on magnetic cards by sending two blank cards to the authors, however, the user is cautioned that magnetic cards are not guaranteed to be transportable among all TI-59 calculators.

5. CONCLUSIONS AND RECOMMENDATIONS

A capability for predicting Maximum Usable Frequencies in the HF radio band can be realized with hand-held calculators, and therefore can be widely deployed in the field. An even larger capability can be realized by utilizing custom made modules for the TI-59. Each module provides for 5000 program steps in addition to the normal 960 maximum step capacity of the calculator, and could provide for additional portions of the CLASSIC PROPHET System to be included in calculator implementations, such as the D-region absorption model. Appendix F lists several persons to contact in regard to having custom modules manufactured for the TI-59.

APPENDIX A

BASIC MINIMUF-3.5 PROGRAM LISTING

The BASIC language listing of MINIMUF-3.5 is reprinted here with the permission of R.B. Rose, and serves as a guide for the TI-59 keystroke listing.

```
1000 REM
1010 K7=SIN(L1)*SIN(L2)+COS(L1)*COS(L2)*COS(W2-W1)
1020 G1=ACS(K7 MAX -1+1.0E-5 MIN 1-1.0E-8)
1030 K6=1.59*G1
1040 K6=K6 MAX 1
1050 K5=1/K6
1060 J9=100
1070 FOR K1=1/(2*K6) TO 1-1/(2*K6) STEP 0.9999-1/K6
1080 IF K5=1 THEN 1100
1090 K5=0.5
1100 P=SIN(L2)
1110 Q=COS(L2)
1120 A=(SIN(L1)-P*COS(G1))/(Q*SIN(G1))
1130 B=G1*K1
1140 C=P*COS(B)+Q*SIN(B)*A
1150 D=(COS(B)-C*P)/(Q*SQR(1-C*C))
1160 D=ACS(D MAX -1+1.0E-5 MIN 1-1.0E-8)
1170 W0=W2+SGN(SIN(W1-W2))*D
1180 IF W0=>0 THEN 1200
1190 W0=W0+P1
1200 IF W0<P1 THEN 1220
1210 W0=W0-P1
1220 L0=P0-ACS(C MAX -1+1.0E-5 MIN 1-1.0E-8)
1230 Y1=0.0172*(10+(M0-1)*30.4+D6)
1240 Y2=0.409*COS(Y1)
1250 K8=3.82*W0+12+0.13*(SIN(Y1)+1.2*SIN(2*Y1))
1260 K8=K8-12*(1+SGN(K8-24))*SGN(ABS(K8-24))
1270 IF COS(L0+Y2)>-0.26 THEN 1350
1280 K9=0
1290 G0=0
1300 M9=2.5*G1*K5
1310 M9=M9 MIN P0
1320 M9=SIN(M9)
1330 M9=1+2.5*M9*SQR(M9)
1340 GO TO 1590
1350 K9=(-0.26+SIN(Y2)*SIN(L0))/(COS(Y2)*COS(L0)+1.0E-3)
1360 K9=12-ATN(K9/SQR(ABS(1-K9*K9)))*7.639437
1370 T=K8-K9/2+12*(1-SGN(K8-K9/2))*SGN(ABS(K8-K9/2))
1380 T4=K8+K9/2-12*(1+SGN(K8+K9/2-24))*SGN(ABS(K8+K9/2-24))
```

```
1390 C0=ABS(COS(L0+Y2))
1400 T9=9.7*C0↑9.6
1410 IF T9>0.1 THEN 1430
1420 T9=0.1
1430 M9=2.5*G1*K5
1440 M9=M9 MIN P0
1450 M9=SIN(M9)
1460 M9=1+2.5*M9*SQR(M9)
1470 IF T4<T THEN 1500
1480 IF (T5-T)*(T4-T5)>0 THEN 1510
1490 GO TO 1640
1500 IF (T5-T4)*(T-T5)>0 THEN 1640
1510 T6=T5+12*(1+SGN(T-T5))*SGN(ABS(T-T5))
1520 G9=PI*(T6-T)/K9
1530 G8=PI*T9/K9
1540 U=(T-T6)/T9
1550 G0=C0*(SIN(G9)+G8*(EXP(U)-COS(G9)))/(1+G8*G8)
1560 G7=C0*(G8*(EXP(-K9/T9)+1))*EXP((K9-24)/2)/(1+G8*G8)
1570 IF G0=>G7 THEN 1590
1580 G0=G7
1590 G2=(1+S9/250)*M9*SQR(6+58*SQR(G0))
1600 G2=G2*(1-0.1*EXP((K9-24)/3))
1610 G2=G2*(1+(1-SGN(L1)*SGN(L2))*0.1)
1620 G2=G2*(1-0.1*(1+SGN(ABS(SIN(L0))-COS(L0))))
1630 GO TO 1700
1640 T6=T5+12*(1+SGN(T4-T5))*SGN(ABS(T4-T5))
1650 G8=PI*T9/K9
1660 U=(T4-T6)/2
1670 U1=-K9/T9
1680 G0=C0*(G8*(EXP(U1)+1))*EXP(U)/(1+G8*G8)
1690 GO TO 1590
1700 IF G2>J9 THEN 1720
1710 J9=G2
1720 NEXT K1
1730 J9=J9 MAX 2 MIN 32
1740 RETURN
```

APPENDIX B

TI-59 PROGRAM LISTING

The keystroke listing of the TI-59 program implementation of MINIMUF-3.5 follows. Segments of TI-59 code are cross-referenced to the BASIC program listing.

```
000   76 LBL
001   11   A
002   42 STO
003   18   18
004   99 PRT
005   35 CLR
006   60 DEG   ĪŌĪŌ,20
007   43 RCL
008   15   15
009   75   -
010   43 RCL
011   13   13
012   95   =
013   39 COS
014   65   ×
015   43 RCL
016   12   12
017   39 COS
018   65   ×
019   43 RCL
020   14   14
021   39 COS
022   85   +
023   43 RCL
024   12   12
025   38 SIN
026   65   ×
027   43 RCL
028   14   14
029   38 SIN
030   95   =
031   70 RAD
032   22 INV
033   39 COS
034   42 STO
035   06   06   1030,40,50
036   65   ×
037   01   1
038   93   .
039   05   5
040   09   9
041   95   =
042   32 X:T
043   01   1
044   71 SBR
045   07   07
046   45   95
047   35 1/X
048   42 STO
049   07   07
```

```
050   32 X:T   1080,90
051   01   1
052   67   EQ
053   00   00
054   57   57
055   93   .
056   05   5
057   65   ×   1300,10,20,30
058   43 RCL
059   06   06
060   65   ×
061   05   5
062   95   =
063   32 X:T
064   89   π
065   71 SBR
066   07   07
067   94   94
068   55   ÷
069   02   2
070   95   =
071   38 SIN
072   45 Y^x
073   01   1
074   93   .
075   05   5
076   65   ×
077   02   2
078   93   .
079   05   5
080   85   +
081   01   1
082   95   =
083   42 STO
084   08   08
085   01   1   1060
086   00   0
087   00   0
088   42 STO
089   11   11
090   02   2   1070
091   75   -
092   43 RCL
093   07   07
094   59 INT
095   95   =
096   42 STO
097   09   09
098   01   1   1070 - cont'd
099   75   -
```

```
100   43 RCL
101   07   07
102   95   =
103   55   ×
104   53   (
105   43 RCL
106   09   09
107   75   -
108   01   1
109   54   )
110   85   +
111   43 RCL
112   07   07
113   55   ÷
114   02   2
115   95   =
116   65   ×    1130
117   43 RCL
118   06   06
119   95   =
120   42 STO
121   00   00
122   43 RCL   1100,10,20
123   14   14
124   60 DEG
125   39 COS
126   42 STO
127   01   01
128   35 1/X
129   65   ×
130   53   (
131   43 RCL
132   12   12
133   38 SIN
134   75   -
135   43 RCL
136   14   14
137   38 SIN
138   42 STO
139   02   02
140   65   ×
141   43 RCL
142   06   06
143   70 RAD
144   39 COS
145   95   =
146   55   ÷
147   43 RCL
148   06   06
149   38 SIN   ____

150   65   ×    1140
151   43 RCL
152   00   00
153   38 SIN
154   65   ×
155   43 RCL
156   01   01
157   85   +
158   43 RCL
159   02   02
160   65   ×
161   43 RCL
162   00   00
163   39 COS
164   95   =
165   42 STO
166   03   03
167   02 INV   1220
168   39 COS
169   84 +/-
170   85   +
171   43   (
172   75   -
173   02   2
174   55   ÷
175   42 STO
176   10   10
177   43 RCL   1150
178   00   00
179   39 COS
180   75   -
181   43 RCL
182   03   03
183   65   ×
184   43 RCL
185   02   02
186   95   =
187   55   ÷
188   43 RCL
189   01   01
190   75   -
191   53   (
192   01   1
193   75   -
194   43 RCL
195   03   03
196   38 SIN
197   54   )
198   04 FIX
199   95   =    ____
```

```
200   22  INV   1160,70,80,90,1200,10
201   39  COS
202   65   ×
203   53   (
204   43  RCL
205   13   13
206   75   -
207   43  RCL
208   15   15
209   54   )
210   60  DEG
211   38  SIN
212   69  DP
213   10   10
214   85   +
215   43  RCL
216   15   15
217   65   ×
218   89   π
219   55   +
220   01   1
221   08   8
222   00   0
223   95   =
224   32  X:T
225   89   π
226   65   ×
227   02   2
228   85   +
229   32  X:T
230   95   =
231   22  INV
232   77   GE
233   02   02
234   38   38
235   75   -
236   32  X:T
237   95   =
238   32  X:T
239   93   .     1230
240   00   0
241   01   1
242   07   7
243   02   2
244   65   ×
245   53   (
246   01   1
247   00   0
248   85   +
249   43  RCL
250   17   17
251   85   +
252   03   3
253   00   0
254   93   .
255   04   4
256   65   ×
257   53   (
258   43  RCL
259   16   16
260   75   -
261   01   1
262   95   =
263   42  STO
264   00   00
265   70  RAD   1240
266   39  COS
267   65   ×
268   93   .
269   04   4
270   00   0
271   09   9
272   95   =
273   42  STO
274   01   01
275   32  X:T   1250
276   65   ×
277   03   3
278   93   .
279   08   8
280   02   2
281   85   +
282   01   1
283   02   2
284   85   +
285   93   .
286   01   1
287   03   3
288   65   ×
289   53   (
290   43  RCL
291   00   00
292   38  SIN
293   85   +
294   01   1
295   93   .
296   02   2
297   65   ×
298   53   (
299   43  RCL
```

300	00	00	
301	65	×	
302	02	2	
303	54	)	
304	38	SIN	
305	95	=	
306	75	-	1260
307	32	X:T	
308	02	2	
309	04	4	
310	95	=	
311	32	X:T	
312	75	-	
313	01	1	
314	02	2	
315	65	×	
316	53	(	
317	01	1	
318	85	+	
319	32	X:T	
320	69	OP	
321	10	10	
322	42	STO	
323	00	00	
324	54	)	
325	65	×	
326	43	RCL	
327	00	00	
328	50	I×I	
329	95	=	
330	42	STO	
331	00	00	
332	93	.	1270
333	02	2	
334	06	6	
335	94	+/-	
336	32	X:T	
337	43	RCL	
338	01	01	
339	85	+	
340	43	RCL	
341	10	10	
342	95	=	
343	39	COS	
344	42	STO	
345	02	02	
346	77	GE	
347	04	04	
348	60	60	
349	00	0	1280,90

350	42	STO	
351	03	03	
352	34	√X	1590
353	65	×	
354	05	5	
355	08	8	
356	85	+	
357	06	6	
358	95	=	
359	34	√X	
360	65	×	
361	43	RCL	
362	08	08	
363	65	×	
364	53	(	
365	01	1	
366	85	+	
367	43	RCL	
368	19	19	
369	55	÷	
370	02	2	
371	05	5	
372	00	0	
373	95	=	
374	65	×	1600
375	53	(	
376	01	1	
377	75	-	
378	93	.	
379	01	1	
380	65	×	
381	53	(	
382	43	RCL	
383	03	03	
384	55	÷	
385	03	3	
386	75	-	
387	08	8	
388	54	)	
389	22	INV	
390	23	LNX	
391	95	=	
392	65	×	1610
393	53	(	
394	01	1	
395	85	+	
396	93	.	
397	01	1	
398	65	×	
399	53	(	

```
400   01   1
401   75   -
402   53   (
403   43 RCL
404   12   12
405   65   ×
406   43 RCL
407   14   14
408   54   )
409   69 DP
410   10   10
411   95   =
412   65   ×      1620
413   53   (
414   01   1
415   75   -
416   93   .
417   01   1
418   65   ×
419   53   (
420   01   1
421   85   +
422   53   (
423   43 RCL
424   10   10
425   38 SIN
426   50 I×I
427   75   -
428   43 RCL
429   10   10
430   39 COS
431   54   )
432   69 DP
433   10   10
434   95   =
435   32 X:T
436   43 RCL    1700
437   11   11
438   71 SBR
439   07   07
440   94   94
441   42 STO
442   11   11
443   97 DSZ    1070,1720
444   09   09
445   00   00
446   98   98
447   32 X:T    1730,40
448   02   2
449   71 SBR
450   07   07
451   95   95
452   32 X:T
453   05   5
454   00   0
455   71 SBR
456   07   07
457   94   94
458   99 PRT
459   91 R/S
460   93   .      1350,60
461   02   2
462   06   6
463   94 +/-
464   85   +
465   43 RCL
466   01   01
467   38 SIN
468   65   ×
469   43 RCL
470   10   10
471   38 SIN
472   95   =
473   55   ÷
474   53   (
475   43 RCL
476   01   01
477   39 COS
478   65   ×
479   43 RCL
480   10   10
481   39 COS
482   85   +
483   93   .
484   00   0
485   00   0
486   01   1
487   95   =
488   32 INV
489   38 SIN
490   65   ×
491   07   7
492   93   .
493   06   6
494   04   4
495   94 +/-
496   85   +
497   01   1
498   02   2
499   95   =
```

```
500   42 STO
501   03   03
502   43 RCL   1370
503   00   00
504   75   -
505   43 RCL
506   03   03
507   55   ÷
508   02   2
509   95   =
510   85   +
511   32 X↕T
512   01   1
513   02   2
514   65   ×
515   53   (
516   32 X↕T
517   69 DP
518   10   10
519   94 +/-
520   85   +
521   32 X↕T
522   01   1
523   54   )
524   65   ×
525   32 X↕T
526   50 I×I
527   95   =
528   42 STO
529   04   04
530   43 RCL   1380
531   00   00
532   85   +
533   43 RCL
534   03   03
535   55   ÷
536   02   2
537   75   -
538   32 X↕T
539   02   2
540   04   4
541   95   =
542   32 X↕T
543   75   -
544   01   1
545   02   2
546   65   ×
547   53   (
548   32 X↕T
549   69 DP
```

```
550   10   10
551   85   +
552   32 X↕T
553   01   1
554   54   )
555   65   ×
556   32 X↕T
557   50 I×I
558   95   =
559   42 STO
560   05   05
561   43 RCL   1390,1400,10,20
562   02   02
563   50 I×I
564   42 STO
565   00   00
566   45 Y^x
567   09   9
568   93   .
569   06   6
570   65   ×
571   09   9
572   93   .
573   07   7
574   95   =
575   32 X↕T
576   93   .
577   01   1
578   71 SBR
579   07   07
580   95   95
581   42 STO
582   01   01
583   65   ×   1530,1650
584   89   π
585   55   ÷
586   43 RCL
587   03   03
588   95   =
589   42 STO
590   02   02
591   43 RCL   1470
592   04   04
593   75   -
594   43 RCL
595   05   05
596   95   =
597   69 DP
598   10   10
599   65   ×
```

```
600   53   (
601   43 RCL
602   18   18
603   75   -
604   43 RCL
605   04   04
606   54   )
607   65   ×
608   53   (
609   43 RCL
610   05   05
611   75   -
612   43 RCL
613   18   18
614   54   )
615   95   =
616   32 X↕T
617   00   0
618   22 INV
619   77   GE
620   07   07
621   35   35
622   43 RCL   1510
623   18   18
624   85   +
625   01   1
626   02   2
627   65   ×
628   53   (
629   53   (
630   43 RCL
631   04   04
632   75   -
633   43 RCL
634   18   18
635   54   )
636   69 DP
637   10   10
638   85   +
639   32 X↕T
640   01   1
641   54   )
642   65   ×
643   32 X↕T
644   50 I×I
645   75   -   1520
646   43 RCL
647   04   04
648   95   =
649   65   ×
```

```
650   32 X↕T
651   89   π
652   55   ÷
653   43 RCL
654   03   03
655   95   =
656   42 STO
657   05   05
658   32 X↕T   1550
659   94 +/-
660   55   ÷
661   43 RCL
662   01   01
663   95   =
664   22 INV
665   23 LNX
666   75   -
667   32 X↕T
668   39 COS
669   95   =
670   65   ×
671   43 RCL
672   02   02
673   85   +
674   43 RCL
675   05   05
676   38 SIN
677   95   =
678   65   ×
679   43 RCL
680   00   00
681   55   ÷
682   53   (
683   01   1
684   85   +
685   43 RCL
686   02   02
687   33 X²
688   54   )
689   42 STO
690   04   04
691   95   =
692   32 X↕T
693   43 RCL   1560
694   00   00
695   65   ×
696   43 RCL
697   02   02
698   65   ×
699   53   (
```

```
700   53   (
701   43 RCL
702   03   03
703   94 +/-
704   55   ÷
705   43 RCL
706   01   01
707   54   )
708   22 INV
709   23 LNX
710   85   +
711   01   1
712   54   )
713   65   ×
714   53   (
715   43 RCL
716   03   03
717   55   ÷
718   02   2
719   75   -
720   01   1
721   02   2
722   54   )
723   22 INV
724   23 LNX
725   55   ÷
726   43 RCL
727   04   04
728   95   =
729   71 SBR   1570,80
730   07   07
731   95   95
732   61 GTO
733   03   03
734   52   52
735   43 RCL   1640,60
736   05   05
737   75   -
738   43 RCL
739   18   18
740   75   -
741   32 X:T
742   01   1
743   02   2
744   65   ×
745   53   (
746   32 X:T
747   69 OP
748   10   10
749   85   +
```

```
750   32 X:T
751   01   1
752   54   )
753   65   ×
754   32 X:T
755   50 I×I
756   95   =
757   55   ÷
758   02   2
759   95   =
760   22 INV   1680
761   23 LNX
762   65   ×
763   53   (
764   53   (
765   43 RCL
766   03   03
767   94 +/-
768   55   ÷
769   43 RCL
770   01   01
771   54   )
772   22 INV
773   23 LNX
774   85   +
775   01   1
776   54   )
777   65   ×
778   43 RCL
779   02   02
780   65   ×
781   43 RCL
782   00   00
783   55   ÷
784   53   (
785   01   1
786   85   +
787   43 RCL
788   02   02
789   33 X²
790   95   =
791   61 GTO
792   03   03
793   52   52
794   22 INV   MIN/MAX
795   77   GE   SUBROUTINE
796   07   07
797   99   99
798   32 X:T
799   92 RTN
```

APPENDIX C

PROGRAM LOGIC MODIFICATIONS

The following program logic changes were made to the BASIC version of MINIMUF-3.5 to minimize program storage requirements:

(1) The computation of M9 at lines 1300-1330 and 1430-1460 is independent of the main loop and was moved to the beginning of the program, immediately following the calculation of G1 and K5.

(2) The loop index computation at line 1070 was separated into a computation of a new variable, KHOP, which is either 1 or 2, and a follow-on computation of K1 from KHOP as the first item within the loop.

(3) The computation of G8 at lines 1530 and 1650 is common to both legs of the preceeding test for (T5-T4)(T-T5), and has been moved ahead of that test.

(4) The test at line 1470 serves to reverse the sense of the following tests at lines 1480 and 1500. This logic has been combined into a single test on (T5-T4)(T-T5) with a weighting factor of 1 or -1 to reverse the sense of that test.

(5) The computation at line 1360 was simplified to the arcsine by way of trigonometric identity.

(6) The MUF limit established at line 1730 was changed to 50 vice 32 to accomodate high solar flux densities.

(7) Throughout the program, explicit calculation and storage of variables that are used only once in following statements has been eliminated to conserve on data register requirements.

APPENDIX D

PROGRAM OPERATING INSTRUCTIONS

The following instructions must be followed to operate the TI-59 version of MINIMUF-3.5:

(1) Repartition the calculator for 800 program steps and 20 data registers by pressing 2/OP/17.

(2) Load the 4 memory banks from program cards (2) or by entering program keystrokes with the calculator in the LRN mode.

(3) Enter input data as follows:

(a) Transmitter North Latitude in decimal degrees in R12 (range -90 degrees to 90 degrees)

(b) Transmitter West Longtitude in decimal degrees in R13 (range 0 to 360 degrees)

(c) Receiver North latitude in decimal degrees in R14 (range -90 to 90 degrees)

(d) Receiver West Longtitude in decimal degrees in R15 (range 0 to 360 degrees)

(e) Month in R16 (range 1 to 12)

(f) Day in R17 (range 1 to 31)

(g) Sunspot Number in R19 (range - positive number)

(4) Enter Time in X-register (range 0 to 24 decimal hours)

(5) Press A

(6) If a printer is attached, the input time is echoed, followed by the answer (MUF) after 50 seconds for single-hop and 100 seconds for two-hop predictions.

(7) The answer is displayed in the X-register when the program halts.

(8) All input quantities remain undisturbed in R12 thru R19 (time is stored by the program in R18). Another MUF for a different time can be computed directly by repeating steps (4) and (5).

APPENDIX E

TEST CASE

The test case that follows was provided in the NOSC report on MINIMUF-3.5. The actual printer listing of input and program output is included.

CONTENTS	REG	
21.	12	(L1)
156.	13	(W1)
38.	14	(L2)
122.	15	(W2)
10.	16	(M0)
17.	17	(D6)
0.	18	
110.	19	(S9)

INPUT

OUTPUT	
0.0	(Time)
36.3	(MUF)
1.0	
35.0	(etc)
2.0	
32.9	
3.0	
29.9	
4.0	
25.0	
5.0	
22.8	
6.0	
20.9	
7.0	
19.3	
8.0	
18.0	
9.0	
16.9	
10.0	
16.0	
11.0	
15.2	
12.0	
14.6	
13.0	
14.1	
14.0	
13.7	
15.0	
21.0	
16.0	
27.6	
17.0	
31.5	
18.0	
34.0	
19.0	
35.6	
20.0	
36.7	
21.0	
37.3	
22.0	
37.5	
23.0	
37.1	

OUTPUT

APPENDIX F

TI-59 CUSTOM MODULES

The following points of contact are provided for the design and manufacture of TI-59 custom modules. Both Texas Instruments and Horizons Technology (contracting with TI) provide software, emulator, and consulting support for the design and production of custom modules. Costs quoted at this time are approximately $12,000 for a minimum order of 250 modules. This includes emulator support and manufacture, but does not include software consulting. Cost reduction through quantity is available.

Fred Wilke
TI-59 Custom Module Division
Texas Instruments
Lubbock, TX
(806) 741-3240

Robert Kruger
Horizons Technology, Inc.
7830 Clairemont Mesa Boulevard
San Diego, CA 92111
(714) 292-8331

LIST OF REFERENCES

1. Rose, R.B. and Martin, J.N., "MINIMUF-3.5, Improved Version of MINIMUF-3, A Simplified HF MUF Prediction Algorithm", Technical Document 201, Naval Ocean Systems Center, San Diego, 26 October 1978.

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